by means of rigid surfaces, the stability asked for being somewhat similar to that of a Canadian canoe, which allows rolling up to a certain inclination for very small movements of the occupant, but offers great resistance to any motion beyond that limit. Such stability, if realisable, would leave the aeroplane sensitive to the pilot's control except in cases of emergency, when the aeroplane had departed considerably from its position of equilibrium, when it would assist the pilot to regain control. If, alternatively, it should ultimately be decided that the pilot must be assisted automatically, then some such device as the Clarke Johnson gyroscopic control exhibited might be used.

SCIENCE AT RECENT EDUCATIONAL CONFERENCES.

IN a previous article (January 23) reference was made to the teaching of physiology and hygiene in schools. At the London County Council Conference of Teachers a considerable portion of the programme was concerned, directly or indirectly, with these subjects. Prof. Starling presided at the fourth session, and referred to the training in physiology of the teacher and the training in physiology or hygiene of the child. It was sufficient if the child was brought up with the knowledge of the rules of right living, but these rules were founded on physiology, and the teacher must have reason for the faith that was in him. On that ground the Physiological Society had appealed to the Board of Education to provide additional facilities for the study of physiology by teachers, and to make such study compulsory.

At the same meeting Prof. Leonard Hill gave an address on open-air and exercise, Mrs. Truelove read a paper on instruction in infant care in girls' schools, and Mr. A. J. Green discussed the value of the open-air school. It is further to be noted that, at each of the three preceding sessions of this conference, subjects bearing closely on the health of the children were brought forward, and the medical profession figured prominently in the discussions. As we are all aware, the tendency to pay regard to the physical welfare of school children is prominent in the programmes of other educational meetings—*e.g.* British Association, Section L. Why this exceptional solicitude at the present time?

It may be granted that administrative and political factors have given much strength to this movement, but there are perhaps somewhat deeper reasons for the ready response of teachers to the call now made upon them to regard their work as one of the agents in determining the health of the nation in years to come. One of these deeper reasons is that biology, with her handmaiden evolution, is come into her own. The child is viewed as an organism; teachers and administrators are thinking biologically. The old platform tag, *mens sana in corpore sano,* implied a dualitv of mind and body, whereas to-day we recognise that the *mens* and *corpus* are educationally inseparable. The psychology of McDougall and the newer school is the offspring of a union of the old psychology with biology—it is not a mere change of the old, but a new-born science. And of this new source of inspiration teachers are drinking in increasing numbers.

The papers of the third session of the L.C.C. Conference were devoted entirely to an exposition of the modern teachings of psychology on the subject of attention. Prof. Spearman, who presided, stated the relations between psychology and education as those of "equal allies who had a joint mission—perhaps the greatest national mission—the making of the nation itself." The words just quoted give the clue to the other great influence which, side by side with psychology—the thinking biologically of the individual—is now influencing the trend of educational ideals and progress. This second influence is to be found in the growing sense of social and economic interdependence—the thinking biologically of communities—the viewing of the State as an organism, and even of world-commerce as an organism. Hence the feeling that an education lacks an important essential which neglects that promising avenue of human progress—the study of economics. There also flows from this sense of social solidarity an increased sense of responsibility for the economic conditions affecting the lives of the poorer classes.

These trends of thought and feeling found respective expression in the educational conferences in the discussions on economics for schoolboys at the L.C.C. Conference, when secondary education was being discussed, and in those on household economics of the poor, at the meeting of Teachers of Domestic Subjects. At this meeting Mr. J. Wilson proposed to weave the two threads of State and domestic economics when he suggested that, in the allocation of the State Development grants, the claims of investigation into possible improvements of methods or appliances used in household work should receive consideration.

That thousands of teachers assembled during their Christmas holidays in twenty conferences in order to "talk shop" shows to every thoughtful person that the teaching profession is spiritually sound. This article fails if it does not indicate, however imperfectly, that the profession is studying its calling with the methods of science, and is no longer satisfied with empiricism. The growth of a body of educational workers thus animated with scientific purpose is the best warrant, if not of the present existence, at least of the imminent development, of a science of education.

G. F. DANIELL.

MODERN MICROSCOPICAL OPTICS WITH SPECIAL REFERENCE TO FLUORITE OBJECTIVES.

GAUSS'S theory of lenses and other optical systems, which was published in 1840 in his "Dioptrische Untersuchungen," and subsequently largely extended by many other investigators, rendered it possible to apply the cardinal theorems relating to the formation of optical images to the most complicated systems of lenses, of which already in Gauss's time the microscope objectives furnished a good example. This theory paved the way for the computation of microscopic objectives and furnished a means of studying the optical principles of the microscope as a whole and the objective and eyepiece considered separately.

Even before Gauss, Fraunhofer in 1820 had succeeded in devising a complete system, enabling him to compute telescope lenses, and a little later Seidel and Steinheil evolved a similarly complete system for the computation of photographic lenses.

Prof. E. Abbe, who in 1866 became associated with the optical establishment of Carl Zeiss in Jena, was the first to venture upon a complete calculation of the microscope objective by applying the theory of Gauss. After a series of futile attempts, he established a system by which a microscope objective could be computed in every detail. The methods by which he applied his system to practical computations have not been made known.

A further valuable contribution to practical optics was made by Helmholtz and Abbe, who, by discovering the sine condition, showed the means by which an object and its image can be made geometrically similar. It is, however, a great mistake to suppose that these achievements in the mathematical equipment of the microscope inaugurated a brilliant epoch in the history of the microscope, and that enormous progress was made henceforth. In the first place, it was found that by a carefully developed trial-and-error system opticians had succeeded in producing objectives which in a high degree satisfied the conditions postulated by mathematical theory. Thus it was found that all objectives tested by Abbe completely satisfied the sine condition, although until then this had been unknown in principle.

The investigations of Helmholtz and Abbe (1873–4) showed by the formula of the former, $\epsilon = \frac{\lambda}{2 \sin \alpha}$, and Abbe's formula, $\epsilon = \frac{\lambda}{2n \sin \alpha}$, that the optical performance of the microscope is confined within definite limits. In these formulæ ϵ denotes the smallest distance separating two successive particles of an object which can be differentiated under a microscope; λ is the wave length of any given ray of light, as defined by Helmholtz, in air or any other medium intervening between the object and the front lens; α is the semi-apertural angle of the objective, and n the refractive index of the medium between the objective and the cover glass. In dry lenses the value of n is accordingly 1·0, in water-immersion it is 1·33, and in oil-immersion lenses $n = 1·52$. The denominator in Abbe's formula, $n \sin \alpha$, has been named by him the numerical aperture of the lens; it furnishes the principal criterion of the optical capacity of the microscope. When these factors, which determine the optical resources of the microscope, were discovered, the microscope had already been brought to a very high degree of perfection by purely empirical means, and in practical respects the formula had already been satisfied to a very considerable extent, and but little scope was left to the investigator and computor. The apertural angle had already attained very considerable magnitudes; water-immersion and oil-immersion lenses were already in existence, and accordingly the element n in Abbe's formula had already received practical consideration, whilst in the formula enunciated by Helmholtz the wave length of a ray in air had become reduced to a quotient $\frac{\lambda}{n}$, by which the wave length was shortened in proportion to the refractive index of the medium.

Amici in Italy, Spencer in America, Fraunhofer, Kellner, Oberhauser, and Hartnack in Germany, Chevalier in France, and Ross and Powell and Lealand in England had all done a great deal to perfect the microscope objective. In medical research a new era had been inaugurated by the achievements of microscopic observations; histology and pathology had been placed upon a firm basis; and Pasteur had already planted the beginnings of bacteriology and identified a number of pathogenic germs. In the face of the difficulties and limited possibilities with which the optician had to contend, it would be interesting to form an estimate of the results which opticians had been able to achieve from the time that they commenced to apply the resources of scientific research. The formula given above made it clear that there was no possibility of extending the capacity of the microscope by increasing without limit its magnifying power. Means had indeed been found to increase the angular aperture α in a measure as the magnification rose higher and higher, but there was a limit beyond which it was impossible to increase the magnifying power of a lens without reducing the free distance between the object and the front lens to an impracticably small amount, which did not even provide room for a thin cover glass. Continued attempts were made to extend the power of the microscope by increasing its magnifying power. It was soon found that lenses having such extremely short focal lengths as 1/20 in. 1/50 in., and even 1/75 in., in which there was no corresponding increase of the angle of aperture, were in no wise superior in their optical capacity to lenses of lower power, and the trouble expended upon them was clearly wasted. These extremely high powers, of which many examples were produced by the opticians of fifty or forty years ago, have now been entirely discarded, and one rarely meets now objectives having a shorter focus than 1/16 in.

Opticians then proceeded to concentrate their efforts upon increasing the numerical aperture. Dry lenses had already then been made with apertures of 0·90, and this value has not been exceeded even in these days. Water-immersion and oil-immersion lenses, with their theoretical apertural limits of 1·32 and 1·52, were, however still far removed from what was practically attainable; in fact, they did not exceed 1·0 in water-immersion and 1·2 in oil-immersion lenses. To carry the aperture further it was necessary to endow the lenses with a greatly improved spherical correction, and much higher demands were made upon the skill of the optician, both in the matter of lens grinding and mounting. By the exercise of an extraordinary degree of skill in the mounting of the front lenses and by clamping them by their extreme ridge, the practical optician has come very near to the theoretical limits, and has been able to realise apertures up to 1·2 in water-immersion lenses and 1·4 in oil-immersion lenses. These were momentous achievements, and it is to lenses of high aperture that bacteriological research owes the greater part of its success. When the limit had been thus reached in both types it was thought to increase the power of the lens by introducing a medium of higher refractive power. Since the transition of light from air ($n = 1$) to water ($n = 1·33$), and that from air to oil ($n = 1·52$) had furnished such striking results, it was expected that the transition to a more highly refracting medium having a refractive index of 1·66 would furnish a means of increasing the aperture still further.

An objective of this kind, in which the immersion medium was monebrome naphthalin, was computed by Prof. Abbe and made by Carl Zeiss in 1889. Its numerical aperture was 1·60. To secure the full advantage of this large aperture it became, however, necessary to satisfy an extensive range of conditions. The condenser must have a similar aperture, both it and object slide required to be joined by a stratum of monebrome naphthalin, and the slide as well as the cover glass had to be made of glass having the same refractive index as the immersion medium, and the object itself had to be mounted in a powerfully refracting medium.

Dr. Van Heurck (Van Heurck, "Le Microscope," 1891, p. 63), who used this objective for a considerable time, and obtained with it many remarkable photographs, including striking photographs of *Amphipleura pellucida*, whilst praising the great resolving power of the objective, described it as scarcely adapted for regular practical use, both on account of the enormous difficulties which its use entails and its inordinately high price. Of the chief causes which militate against the use of the objective, and indeed render it almost impracticable, Czapski remarks in the *Zeitschrift fur wissensch. Mikroskopie,* vol. viii., 1891, p. 149, as follows:—Organic preparations require from their very nature to be embedded in media which in the majority of cases have a much lower refractive index than the immersion fluid for which the objective has been computed. This excludes all these preparations from observation with the monebrome naphthalin lens, since one of the principal conditions for the successful use of the lens remains unfulfilled. Even the difficulties which attend the use of the objective and its high price could never have been regarded as a sufficient reason for dispensing with its services if any considerable range of objects existed which could bear being embedded in the media having the requisite optical properties, and in which the capacity of the lens could be turned to full account. As it is, the objective is only known by the photographs taken by Van Heurck, and, as a matter of fact, the lens has long ceased to be manufactured.

There is yet another way of enhancing the working capacity of a lens, as will be seen from the formulæ of Helmholtz. The wave length of light may be reduced by working with white light having a wave length of 0·00055 mm., or blue light having a wave length of 0·00043 mm., or ultra-violet light having a wave length of 0·00028 mm. Blue light reduces by about 1/4–1/5 of its original value, whilst ultra-violet light reduces it to about one-half. A few years ago Dr. A. Koehler investigated successfully what might be accomplished in this direction by the use of light of extremely short wave lengths (*Zeitschr. f. wiss. Mikr.,* vol xxi., 1904, p. 129 *et seq.*). An elaborate new apparatus was required to obtain tangible results from the application of very short waves. Even the best glasses that will transmit ultra-violet light did not suffice for the purposes of this investigation, and the only materials which transmitted ultra-violet light of sufficient intensity were fused quartz and fluorspar. The condenser, the object slide, cover glass, objectives, and eyepieces had all to be made from either of these materials, whilst glycerin served as the immersion fluid. Only a limited number of mounting media were available for use with this apparatus. The lacking intensity of this light rendered it impossible to apply it visionally, and recourse was accordingly had to the photographic method. The difficulties encountered in focussing the object have been overcome by the application of fluorescent light.

The greatest difficulties were encountered in the construction of the objectives. Owing to the limited choice of materials it was impossible to attempt to make the lens achromatic, and indeed this was scarcely a matter of importance, seeing that the light used is almost monochromatic. On the other hand, the use of simple lenses made it impossible to secure spherical correction with respect to more than a small central aperture. This applies at least to a high power dry lens and to an oil-immersion lens of lower power.

There is another circumstance which was found to be a serious drawback, in that the lenses of the objectives had necessarily to be mounted without the usual adjustments by means of which departures in the radii, thickness, distance between the lenses, and irregularities in the homogeneity of the glasses may be allowed for, since it is almost beyond the resources of a workshop to apply any direct test to lenses corrected with respect to the ultra-violet light. It will be readily appreciated that an objective which is made exclusively on the strength of data obtained by calculation without the controlling aid of the optician's art must necessarily be of the nature of chance products. In these circumstances one may either dispense with the highest degree of perfection by accepting an objective as it leaves the optician's hands, or one may from one of a series of several lenses select the one which is best, by direct observation with a fluorescent screen, with a fluorescent eyepiece, or by photographic tests, but such a proceeding would be inordinately costly. Koehler's investigations have the merit of having clearly demonstrated the almost insuperable difficulties with which one has to contend when attempting to apply ultra-violet light. The photographs which have been obtained so far with the aid of ultra-violet light have scarcely furnished any new aspect of the structure of microscopic objects.

Apochromatic and Fluorite Lenses.

The labours of Abbe and Schott in the study and production of optical glasses, which were begun in 1881, were to a certain extent completed in 1886. In the technical laboratory established by them under the title of Schott und Genossen, they brought out, in addition to the crown and flint glasses then in use, an extensive series of glasses having markedly improved optical properties and of a different chemical composition. By introducing phosphoric acid and boric acid as components of glass smeltings, in addition to silicic acid, they succeeded in producing new crown and flint glasses, the so-called phosphate and borate glasses, in which the rate of change of the dispersion is remarkably proportional, so that it appeared possible by the combination of these glasses partly to eliminate the secondary spectrum, which hitherto it had been impossible to eliminate to any appreciable extent. In the course of time the Schott works introduced an extensive selection of optical glasses, which greatly simplified the computing optician's work. The list includes glasses of similar refringent properties but widely different dispersion, and others again having a similar dispersion but covering a wide range of refractive indices. This was a great advance over the old glasses, in which any increase of dispersion was attended with a rise in the refractive power.

A valuable feature of the new glasses is that the glass works were able to reproduce very closely any of the types specified in their catalogues, and, in addition, every new pot was examined with the spectrometer and its constants recorded. This relieves the computer of the task of having to determine for himself the optical properties of the glasses, and likewise the optician working on the trial-and-error principle was enabled more easily to attain his purpose by a judicious variation of the glasses in accordance with their refractive properties and dispersions. These glasses were used for the first time in apochromatic objectives as originated by Zeiss. This would indeed have been a stupendous achievement if, as the makers of these lenses maintained at first, their success had been solely due to the use of the new phosphate and borate glasses. Unfortunately, as we shall have occasion to show, it was the introduction of fluorite into the composition of the lenses which was responsible for these achievements.

The new objectives, which were completed in 1886, proved a great advertisement for the glass works of Messrs. Schott und Genossen. Of the use of fluorite, however, not a word was uttered, even in a lecture delivered by Abbe on the subject before a scientific gathering and published in the Transactions of the *Jenaische Gesellschaft für Medizin und Naturwissenschaften,* under the title, "Ueber neue Mikroskope," or, as it appeared in a subsequent reprint, "Ueber Verbesserung des Mikroskops mit Hilfe neuer

Arten optischer Gläser." Again, not a word was said of fluorite in a paper entitled, "On Improvements of the Microscope with the Aid of New Kinds of Optical Glass," which appeared in the Journal of the Royal Microscopical Society, vi., 1886, p. 20, *et seq.*; neither was it mentioned in a publication prepared for French readers, and entitled, "Nouveaux Objectifs et Oculaires pour Microscopes construits avec les verres spéciaux de la Verrerie scientifique (Schott et Cie.), par Carl Zeiss, Atelier d'Optique à Iena."

Four years passed before the true facts of the case were made known by the firm of Zeiss in an article published in the *Zeitschrift für Instrumentenkunde*, 1890, p. 1, under the heading, "Ueber die Verwendung des Fluorits für optische Zwecke." Long before the publication of this paper other firms, having failed to produce lenses equivalent to the apochromatic lenses with the aid of the new glasses only, had realised that the great advances in achromatic correction embodied in the apochromatic lenses were not due in the first instance to the use of the new glasses but rather to that of fluorite. Doubtless Abbe had set himself the task of achieving chromatic correction of a higher order by means of the new glasses only, but he failed in accomplishing any very striking results with the aid of these glasses only, and, moreover, the optically most trustworthy glasses could be used in a very restricted sense only, owing to their lack of resistance to atmospheric influences.

We will now briefly discuss the conditions under which glasses combined to form crown and flint glass pairs will furnish a means of securing a more or less complete degree of spherical and chromatic correction.

The older lenses of the achromatic type are composed of two doublet lenses for the lower and moderately high powers, with one or two front lenses of crown glass added for the high powers. The doublet lens consists of a negative flint glass component and a positive crown glass component cemented thereto. The spherical correction is in the main effected at the surface of contact between the components of the doublets. The magnitude of the difference in the refractive indices of the flint and crown glass components governs the curvature of the cemented surfaces, and it should be as high as possible to flatten the surface and to adduce favourable conditions for the correction of the spherical aberration and for securing a high aperture. To eliminate the chromatic aberration the glasses are so chosen that the dispersion of the highly refracting flint may be considerably greater than that of the less refringent crown glass. A good gauge of the dispersive properties of a glass is furnished by the formula $\frac{nD - 1}{nF - nC} = \nu$; nF, nD, nC denote the refractive indices with respect to the rays corresponding to the F, D, and C lines of the spectrum; $nF - nC$ stands for the mean dispersion; $\frac{nF - nC}{nD - 1}$ supplies an expression for the dispersive power, whilst its reciprocal value, usually denoted by the letter ν, is known as the efficiency of the optical medium.

In the list of glasses made by Messrs. Schott and Co. the glasses are arranged in a progressive order of ascending values of the efficiency ν. Glasses in which the value of ν ranges from 75 to 55 are usually classed as crown glasses, whilst those in which ν has a smaller value go by the name of flint glasses. The combination of a positive crown glass lens with a negative flint glass lens affords a means of correcting the chromatic aberration.

A higher degree of achromatisation can be attained, *i.e.* the secondary spectrum may be eliminated and rays made to meet in a point with respect to more than two colours, if glasses are chosen in which the dispersions proceed by proportional steps. The degree to which this requirement is satisfied may be ascertained by dividing the difference of the refractive indices for two fixed lines of the spectrum, say F and G′, *i.e.* the so-called partial dispersion, by the difference of the refractive indices for the interval C to F, the so-called mean dispersion. A pair of crown and flint glasses, in which the quotients $\frac{nG' - nF}{nF - nC}$ differ least will be best adapted for the achromatisation of an optical combination with respect to a third colour.

Achromatic Lenses.

	nD]	ν	q	Δq
Crown 0·60	1·5179	60·2	0·566	43–49
Flint No. 36–38 ...	1·6202–1·6489	36·2–33·8	0·609–0·615	
Pantachromatic Lenses.				
Phosphate crown I.	1·5159	70·0	0.552	15–31
Borate flint	1·5521	53·8	0·567	
,, ,, ...	1·6086	44·3	0·583	
Apochromatic Lenses.				
Fluorite	1·4338	95·4	0·561	2–10
Boro-silicate crown.	1·5100	64·0	0·559	
Barium-silicate crown	1·5399	59·4	0·566	
Dense barium-silicate crown	1·5726	57·5	0.571	

The above table shows in the first section a pair of glasses such as are used to produce an achromatic lens, and it will be seen to what extent the refractive indices of the components nD and the values of ν should differ to effect the requisite spherical and chromatic corrections. It will be seen that the quotients given in the column headed q, viz. $\frac{\text{partial dispersion}}{\text{mean dispersion}}$, differ by an amount $\Delta q = 43$ to 49 units. With this difference remaining there is still a pronounced secondary spectrum, since the imperfect proportionality in the configuration of the spectra due to the glasses renders it impossible to bring three colours to a point.

The second section typifies the new glasses which were employed to effect a higher degree of correction in achromatic lenses. In the first place, the difference in the refringent properties of the phosphate crowns and borate flints was not sufficient to obtain such flat lens curvatures as are needed to ensure a large aperture, at least not with a single pair of glasses. The quotiental difference, Δq, is in these glasses brought down to 15–31. This signifies already a very marked advance, and to improve still further upon it one would have to have recourse to denser flint glasses of greater refractive power so as to obtain better conditions for correcting the spherical aberration by flattening the curvative. Even if it had proved possible, by complicating the formula, to evade the presence of pronounced curvatures and to use glasses of a small quotiental difference only, there would still have remained an insurmountable difficulty in that all borate and phosphate glasses are so little permanent as to exclude their use in lenses. An objective containing elements made up of these materials, whilst produced at a greatly increased cost, could not have failed to become useless in a very short time. Those lens-makers who used these glasses before they had had time to realise their peculiarities had to pay dearly for their subsequent experience.

The third section of the table comprises fluorite and a number of glasses with which it may be associated to form achromatic pairs. The difference in the refractive properties of fluorite and these glasses is not less than in the ordinary glasses, such as enter into the composition of the well-proved older achromatic lenses, and it is sufficiently great to insure the flat curvatures needed for spherical correction. The difference in dispersion is at least equal to that occurring in the achromatic lenses, and hence no obstacles are encountered in bringing two colours to a point. The significant result derived from the use of fluorite is that the difference of the quotients q reduces to 2–10 units, and almost disappears even in some combinations, so that in addition to rays corresponding to the D and F lines of the spectrum a ray of yet another colour, corresponding to G, can be brought to a point. The immense utility of fluorite lies in the fact of its low refractive index being coupled with an extraordinary small dispersion, by which it differs in a striking degree from the glasses, whilst yet the quotient is similar to that of the existing crown glasses. The use of fluorite in the place of the usual crown glass component rendered it possible to replace the ordinary flint component with its disproportional dispersion by a crown glass having either a quotient agreeing with that of fluorite or at least differing but slightly from it.

The older silicate crown glasses, which had so far been used in the composition of achromatic lenses, contain a number of glasses which differ widely from one another in their refractive and dispersional properties, whilst their quotient is much the same as that of fluorite. By combining fluorite with these crown glasses a means was obtained of producing more perfectly achromatic lenses without the need of a new glass.

It will thus be seen that the new glasses were quite a subordinate element in the composition of apochromatic lenses. There is no doubt that their greater range of variety has made it easier to produce apochromatic lenses, but it is not essentially owing to them that apochromatic lenses have come into existence. In 1891 Leitz made an attempt to produce lenses of a higher degree of correction by the use of glasses only. These were the so-called pantachromatic lenses, the optical qualities of which were intermediate between those of the achromatic and apochromatic lenses. The attempt, however, had soon to be discontinued since those glasses which had proved the best means of endowing the pantachromatic lenses with a higher degree of colour correction proved to be liable to deterioration. Within the last ten years several opticians have introduced a new class of objectives, the so-called fluorite lenses, in which the qualities of the former pantachromatic lenses are realised with the aid of fluorite.

These objectives have, so far as the author is aware, the simple composition of the achromatic lenses, and do away with the necessity of introducing a triple lens, which renders them much less costly than the apochromatic lenses. In their degree of colour correction they approximate to apochromatic lenses in proportion to the number of fluorite lenses used in the system. Dispensing, however, with the triple lens, they cannot be rendered equivalent to apochromatic lenses, even when the number of fluorite lenses is the same in both systems. On the other hand, it is the presence of the triple lens which adds materially to the cost of the apochromatic lenses.

Reviewing the results achieved within the many years during which the practical optician has been guided and aided by the resources of science, it cannot be said that any epoch-making progress has been made. Yet it cannot be denied that modern men of science and practical opticians have manifested an extraordinary activity in their keen desire to improve the power of the microscope and to extend our knowledge of the instrument.

Comparing the performance of modern lenses with those of thirty years ago one cannot fail to realise that steady progress has been made. An objective of numerical aperture 1·40 is a remarkable piece of work, and there is scarcely a modern lens that does not bear testimony to the fruitfulness of recent efforts. New types of objectives have likewise been devised for the needs of the photographer, and various new devices for observation by dark-ground illumination, especially Leitz's dark-ground condenser, have developed this method of observation in a surprising manner. The indefatigable activity of opticians as well as physicists has elucidated the nature of the problems relating to the limits within which it is possible to improve the microscope, and has given us a better insight into the *modus operandi* of the instrument. It may suffice to remind the reader of Abbe's theory of optical instruments.

To what extent the study of microscopic optics has occupied the minds of research workers is eloquently borne out by the vast literature which during this period deals with the microscope. Of journals devoted to the study of the microscope we may mention the *Zeitschrift für wissenschaftliche Mikroskopie*, the Journal of the Royal Microscopical Society, and the Journal of the Quekett Microscopical Club. The microscope forms also the subject of extensive works, amongst which one may mention those of Abbe, Dippel, Lummer and Reiche, van Heurck, Wright, Spitta, and Carpenter. A number of meritorious works have been published which, whilst dealing with optical matters in general, go far to further the development of microscopical optics. Of the authors who have written on geometrical optics and optical instruments we may mention Ferraris, Herman, Maxwell, Lord Rayleigh, Heath, Gleichen, Drude, Czapski, von Rohr, Whittaker, Gullstrand, Leathem, Schwarzschild, Maclaurin.

It has often been said that the microscope has reached the limits of its resources. Certain it is that it has needed the application of the utmost skill and the most strenuous efforts to enhance the powers of the microscope during recent years. There is, however, every prospect that the ever-extending use of the instrument, the increasing demands made upon it, the intense scientific attention bestowed upon its development, and the fine training of the modern optician will not fail to maintain progress.

C. Metz.

SOME OF THE NEXT STEPS IN BOTANICAL SCIENCE.[1]

When one who has worked long in any field of science speaks before an audience such as this he is expected to say something about the condition of his branch of science when he began work with meagre and poorly adapted apparatus, to contrast it with its greatly improved condition to-day, and to dwell with pride upon the finely equipped laboratories with costly apparatus, especially designed for particular experiments, to be found by the twentieth-century scientific student.

In order that we may properly orient ourselves with reference to the area covered by the science of botany to-day, we shall have to go back a few decades to understand what additions have been made to its territory during this period of expansion.

Consider for a few minutes the botany of forty years

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[1] From an address delivered before the American Association for the Advancement of Science at Cleveland, Ohio, December, 1912, by the retiring president, Prof. C. E. Bessey.